Earned Schedule Leads to Improved Forecasting

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Purpose

To discuss the application of *Earned Schedule* to schedule and cost prediction.
Overview

• **Earned Schedule** Review
• Network Schedule Analysis
• Earned Value Research
• Schedule Performance
• Concept of *Effective Earned Value*
• Forecasting with Effective EV
• Summary
Earned Schedule
Why Earned Schedule?

• Traditional schedule EVM metrics are good at beginning of project
  – Show schedule performance trends

• But the metrics don’t reflect real schedule performance at end
  – Eventually, all “budget” will be earned as the work is completed, no matter how late you finish
  • SPI improves and equals 1.00 at end of project
  • SV improves and concludes at $0 variance
Why Earned Schedule?

- Traditional EVM schedule metrics lose predictive ability over the last third of the project
  - Impacts both schedule & cost predictions

- *Project managers and customers don’t comprehend schedule performance in terms of budget*

  …Like most of us!
Earned Schedule Concept

\[
\text{SPI($)} = \frac{\text{EV}}{\text{PV}}
\]

\[
\text{SV($)} = \text{EV} - \text{PV}
\]

\[
\text{SPI(t)} = \frac{\text{ES}}{\text{AT}}
\]

\[
\text{SV(t)} = \text{ES} - \text{AT}
\]

\[
\text{ES} = \text{All of May} + \text{Portion of June}
\]

\[
\text{ES} = 5 + \frac{\text{EV($) - PV(May)}}{\text{PV(June)} - \text{PV(May)}}
\]

\[
\text{AT} = 7
\]
Earned Schedule Formulae

• $ES_{cum}$ is the:
  Number of completed PV time increments EV exceeds + the fraction of the incomplete PV increment

• $ES_{cum} = C + I$
  $C = \text{number of time increments for } EV \geq PV$
  $I = \frac{(EV - PV_C)}{(PV_{C+1} - PV_C)}$

• $ES_{period(n)} = ES_{cum(n)} - ES_{cum(n-1)}$
  $= \Delta ES_{cum}$
Key Points

• ES indicators are constructed to behave in an analogous manner to the EVM Cost Indicators, CV and CPI
• SV(t) and SPI(t) are not constrained by PV calculation reference (BAC)
• SV(t) and SPI(t) provide duration based measures of schedule performance
## Table of Formulas

<table>
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<th>Metrics</th>
<th>Earned Schedule</th>
<th>ES&lt;sub&gt;cum&lt;/sub&gt;</th>
<th>AT&lt;sub&gt;cum&lt;/sub&gt;</th>
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<tbody>
<tr>
<td><strong>Actual Time</strong></td>
<td></td>
<td>ES = C + I</td>
<td>AT = number of periods executed</td>
</tr>
<tr>
<td><strong>Indicators</strong></td>
<td></td>
<td>SV(t)</td>
<td>SPI(t)</td>
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<tr>
<td>Schedule Variance</td>
<td></td>
<td>SV(t) = ES - AT</td>
<td>SPI(t) = ES / AT</td>
</tr>
<tr>
<td>Schedule Performance Index</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>To Complete Schedule Performance Index</td>
<td></td>
<td>TSPI(t) = (PD – ES) / (PD – AT)</td>
<td>TSPI(t) = (PD – ES) / (ED – AT)</td>
</tr>
<tr>
<td><strong>Predictors</strong></td>
<td>Independent Estimate</td>
<td>IEAC(t)</td>
<td></td>
</tr>
<tr>
<td>at Completion (time)</td>
<td></td>
<td>IEAC(t) = PD / SPI(t)</td>
<td>IEAC(t) = AT + (PD – ES) / PF</td>
</tr>
</tbody>
</table>
Application Results
ES Applied to Real Project Data
Late Finish Project: SV($) and SV(t)

Commercial IT Infrastructure Expansion Project Phase 1
Cost and Schedule Variances
at Project Projection: Week Starting 15th July xx

Stop wk 19
Sched wk 20
Re-start wk 26
Duration Prediction
IEAC(t) Prediction Comparison
Early and Late Finish Project Examples

In both examples, the **pre ES** predictors (in red) **fail** to correctly calculate the Actual Duration at Completion!

The ES predictor, SPI(t) alone **correctly** calculates the Actual Duration at Completion in both cases.
Schedule Analysis
Schedule Analysis with EVM?

- The general belief is EVM cannot be used to predict schedule duration
- Most practitioners analyze schedule from the bottom up using the networked schedule ….“It is the only way possible.”
  - Analysis of the Schedule is overwhelming
  - Critical Path is used to shorten analysis
    (CP is longest path of the schedule)
- Duration prediction using Earned Schedule provides a macro-method similar to the method for estimating Cost
  - a significant advance in practice
- But, there’s more that ES facilitates ….
Earned Schedule

Bridges EVM to Network Schedule
How Can This Be Used?

- **Tasks behind** – possibility of impediments or constraints can be identified
- **Tasks ahead** – a likelihood of future rework can be identified
- The identification is independent from schedule efficiency
- The identification can be automated

• **PMs can now have a schedule analysis tool connected to the EVM Data!!**
Earned Value Research
Earned Value Research

• Most research conducted since 1990
  – Result of cancellation of Navy A-12 Avenger
  – Primary researcher, Dr. David Christensen, Southern Utah University
  – Cost studies using very large DOD projects

• EVM Literature on Dr. Christensen’s website

  http://www.suu.edu/faculty/christensend/ev-bib.html
Results from EV Research

• Dr. Christensen’s & associates’ findings
  – CPI stabilizes @ 20% complete
  – CPI tends to worsen as EV ⇒ BAC
  – |CPI(final) – CPI(20%)| ≤ 0.10
  – IEAC = BAC / CPI ≤ Final Cost

  *when Percent Complete is 20% ⇔ 70%*
Research Discussion

• CPI tends to worsen as EV ⇒ BAC
• IEAC = BAC / CPI ≤ Final Cost
  \[\text{when Percent Complete is 20\% } \Leftrightarrow 70\%\]
• IEAC condition must be true if CPI tendency is true
• Rationale supporting CPI tendency
  – Rework increasing as EV approaches BAC
  – Late occurring impacts from constraints/impediments
  – Lack of available EV toward end of project
• My conjecture: \( SPI(t) & IEAC(t) = PD / SPI(t) \) behave similarly to CPI & IEAC = BAC / CPI
CPI & IEAC Behavior

CPI<sub>cum</sub> versus Percent Complete

IEAC Behavior

Percent Difference

(IEAC - Final Cost) / Final Cost

Percent Complete
Schedule Performance
Earned Schedule

Bridges EVM to Network Schedule
Schedule Performance

• EV isn’t connected to task sequence
  – Hypothesis: Completion sequence of tasks affects performance efficiency
• Incorrect task sequencing occurs when there is …
  – Impediment or constraint
  – Poor process discipline
• Improper performance sequence may cause …
  – Overloading of constraint
  – Performance of tasks w/o complete inputs
Schedule Performance

• Result from improper performance sequence …
  – Constraint limited output
    • Schedule lengthens
    • Cost increases while waiting (when other EV available is severely limited)
  – Rework occurs (~ 50%)
    • Schedule lengthens
    • Cost escalates
• Constraint problem & Rework appear late causing …
  – CPI & \( SPI(t) \) to decrease as EV \( \Rightarrow \) BAC
Schedule Adherence Measure

- Schedule Adherence measure is proposed to enhance the EVM measures
  - Early warning for later cost and schedule problems
  - Proposed Measure: In accordance with the project plan, determine the tasks which should be completed or started for the duration associated with ES. Compare the associated PV with the EV of the tasks which directly correspond. Calculate the ratio:

\[
P = \frac{\text{Tasks (correspond)}}{\text{Tasks (plan)}} = \frac{\sum EV_j (\text{correspond})}{\sum PV_j (\text{plan})}
\]

where \( \sum EV_j \leq \sum PV_j \) & \( \sum PV_j = EV \)
Schedule Adherence Measure

• Characteristics of the P measure
  – P measure cannot exceed 1.0
    \[ 0 \leq P \leq 1.0 \]
  – At project completion P = 1.0
  – P is likely unstable until project has accumulated a sufficient amount of data \{similar to the behavior of CPI\}

• P used to compute effective earned value \{EV(e)\}
Effective Earned Value
Effective Earned Value

\[ \Sigma EV_j \leftarrow PV @ ES \]

- EV(r) is performed at risk of creating rework
- Portion colored \( \square \) is usable
- Portion colored \( \square \) is unusable

Total EV

Effective EV
Effective Earned Value

• Effective earned value is a function of EV, P, and Rework

\[ EV(e) = f (EV, P, Rework) \]

• \[ EV(e) = \left( \frac{1 + P \times R\%}{1 + R\%} \right) \times EV \]

R\% = Rework Percent

R\% = fraction of EV(r) unusable ÷ by fraction of EV(r) usable

\( EV(r) = \sum PV_j - \sum EV_j \)

• \[ EV(e) = \left( \frac{P + 2}{3} \right) \times EV \]

when R\% = 50\%
Effective Earned Value

• Effective ES is computed using EV(e) \{i.e., ES(e)\}

• Effective EV indicators are …
  – CV(e) = EV(e) – AC
  – CPI(e) = EV(e) / AC
  – SV(te) = ES(e) – AT
  – SPI(te) = ES(e) / AT

• *The behavior of P may explain Dr. Christensen’s findings for CPI & IEAC*
Graphs of CPI, CPI(e) & P - Factor (notional data)
Graphs of CPI, CPI(e), & P - Factor (real data)
Recap - Effective Earned Value

• Lack of adherence to the schedule causes EV to misrepresent project progress
• P indicator introduced to measure schedule adherence
• Effective EV calculable from P, R% and EV reported

• Prediction for both final cost and project duration hypothesized to be improved with **Effective Earned Value**
Forecasting with Effective Earned Value
**Forecasting using Effective Earned Value**

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<th>Cost Prediction</th>
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<td>IEAC(te) = PD / SPI(te)</td>
<td>IEAC(e) = BAC / CPI(e)</td>
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Schedule & Cost Prediction
(notional data)

Cost Forecast Comparison

- BAC = $1,000,000
- Percent Complete: 0.2, 0.4, 0.6, 0.8, 1.0
- IEAC(e)
- IEAC

Schedule Forecast Comparison

- IEAC(te)
- IEAC(t)
- PD = 36 months
- Months: 35, 37, 39, 41, 43, 45
Summary
Summary

• ES derived from EVM data … only
• Indicators do not fail for late finish projects
• Schedule prediction is better than any other EVM method presently used
• Application is scalable up/down, just as is EVM
• *Facilitates bridging EVM to the schedule*
• Leads to Schedule Adherence & Effective Earned Value, and …

• *Improved Cost & Schedule Forecasting*
References

• “Schedule is Different,” *The Measurable News*, March & Summer 2003 [Walt Lipke]

Earned Schedule Website: [www.earnedschedule.com](http://www.earnedschedule.com)
Click “Education,” then “Presentations and Papers”